NON METRIC CAMERAS
IN
ARCHITECTURAL PHOTOGRAMMETRY

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ABSTRACT

Historical buildings and ancient monuments are valuable cultural heritage of nations, that are unfortunately being damaged due to human interference, weather conditions and environmental pollution. So, it is necessary to record all of them in a rapid and easy manner, in order that archaeological studies and establishment of a National Heritage Archive becomes possible. Close Range Photogrammetry(CRP) with interesting and unique capabilities is the most useful tool for this purpose. The difficulty in traditional photogrammetry is the necessity of metric camera that is expensive, hard to access(especially in countries such as Iran that are rich in cultural heritage), far from user-friendliness and needs special processing instruments. Such factors reduce the degree of usefulness and easiness of CRP technology. There are a lot of historical monuments in Iran(which many of them are in the level of the most important cultural heritage of the world) and in the present project one of them i.e. the relief of Driush I, the Great(500 B.C.) on the rocks of Bisotun was choosen as the test field. This splendid monument is, nationally and internationally, highly discussed and there is an emergent programme in hand for its conservation and restoration. The present project is concentrated on the application of professional and amateur non metric cameras. These cameras have unknown calibration parameters that are usually photo variant. The kernel of this research is firstly to have a survey on the calibration elements of non metric cameras(that are easily available) and secondly to show the photogrammetric capabilities of a precise non metric(Hasselblad), an amateur(Yashica), and a digital(Minolta) camera from the stereoplotting and rectification point of view.

1 INTRODUCTION

Experience has shown that accuracy, productivity, reliability, and fidelity of photogrammetric survey is higher than what can be obtained by any other traditional direct method of measurement. In photogrammetry, the term *close range* generally refers to a finite camera-to-object distance. In close range photogrammetry(CRP), absolute orientation with respect to control points does not play a significant role. What is important is to measure the relative positions of points on the surface of an object, and determine its size, shape or volume according to desired accuracy. Sometimes, close range photogrammetry falls under the category of terrestrial photogrammetry. However, the standard camera used in terrestrial photogrammetry is mainly designed for topographic mapping, usually focused at infinity.CRP covers the most frequent applications of photogrammetry i.e. non topographic photogrammetry which provides an accurate, unique, easy, fast, and inexpensive procedure for measurement and assessment of size and shape, so it is being applied in an ever increasing number of ways; more and more measurement and control problems in many fields of science and technology are being solved by this technique for instance in medicine, industry, and architecture.

1.1 Architectural Photogrammetry

According to the *new concept of conservation* developed in the symposia of ICOMOS(International COuncil of Monuments and Sites) "the conservation and restoration of a monument has to be supported by meticulous statements about its current condition. Such statements express, in particular, the *effective shape* of the monument, in a perfectly objective and complete manner, including all the irregularities, whether wanted or not, important or not, of aesthetic, historic, or technical interest." The most valuable use of CRP in architecture would be in the creation of *national heritage archives* and also providing reliabe records of cultural heritage for their conservation and restoration against the probable catastrophs.

Because of the previously mentioned characteristics of CRP, archaeology and architecture are now important users of this technique, specially with the aid of modern photogrammetric systems based on automated image measurement, its capability is widely recognized. Photogrammetric recording of architectural monuments and cultural heritage has offered substantial time saving and facility over what has been required by traditional methods of hand measurement and drafting.

In addition to ICOMOS, there are several national and international organizations which conduct or support projects on the application of photogrammetry for cultural heritage conservation. Among these organizations two institutions are of more importance: UNESCO(United Nations Educational, Scientific, and Cultural Organization) which recommends the use of photogrammetry, takes charge of actions relating to education in this field, contributes to the establishment of laboratories to undertake surveys, and makes the decision to require photogrammetric surveys as a prerequisite for all large international operations for safeguarding monuments or sites and CIPA(International Committee on Architectural Photogrammetry) whose activities consists of publications, contacts with numerous correspondents throuout the world, and organizing meetings of experts.

For the convenience of treatment, three main categories can be considered in architectural photogrammetric surveys:

I) Simple Surveys. Surveys of this type are used in preliminary studies for restoration or development, in inventory work, in the study of the history of art, etc. An accuracy of 5 cm is often considered sufficient and the plotting is generally at scales 1:100 or 1:200.

II) Precise Surveys. This group of architectural photogrammetric surveys corresponds to the more general requirements of architects or art historians and is undertaken in the framework of survey programs of conservation of heritage conducted by official organizations. Surveys of this type are used in several fields such as analysis of monuments, conservation and restoration, systematic recording of major monuments, developments of facades, surveys of monument decorations, and delicate archaeological surveys. In these surveys, the accuracy called for is 1 or 2 cm and plotting is generally at a scale of 1:50.

III) Very precise Surveys. This group of surveys involve certain aspects of the knowledge of the monuments and their conservation. These surveys are mainly used for highly refined studies as the case of carved elements on which a typological work is undertaken, or in providing reproduction without making a casting of the original. The other application of very precise surveys involves the fine analysis of a surface for which recordings provide very useful information. Thus the research studies on the degradation of the surface of the monuments due to *disease of stone* can follow the progression of the disease, and the thickness of the material destroyed by break-ups can be determined using periodic photogrammetric surveys and comparing them with stable references. The desired accuracy in these surveys is 1mm and, in some cases, 0.1 mm.

In summary, architectural application of modern photogrammetry(analytical and digital systems) show the best performance in quality, accuracy, and cost.

1.2 Non Metric Cameras

Cameras used in photogrammetry are devided into two groups; metric and non metric. By definition, a metric camera has known interior orientation and calibrated radial distortion. The distortions are too small to be considered in practical applications. Metric cameras are equipped with fiducial marks and film flattening device, but very expensive, hardly accessible and difficult to use. These factors have limited the application of metric cameras. Non metric cameras, on the other hand, are not designed especially for photogrammetric purposes. In the design of these cameras the image quality is preferred much more than geometrical accuracy. Non metric cameras have many advantages such as lower cost, general availability, light weight, possibility of being hand held, and flexibility in focusing range. But, non metric camears have also some disadvantages such as relatively poor geometrical accuracy, lack of fiducial marks, unstability of interior orientation, and lack of accessories for exterior orientation. Fortunately, various analytical data reduction methods and softwares are being developed for non metric CRP which can reduce or completely eliminate the disadvantages. Furthermore, because of high flexibility and versatility, non metric cameras are mostly used in the conditions very far from standards for which metric cameras and analogue plotters are designed.

1.3 Camera Calibration

In the standard methods of measurement in photogrammetry it is assumed that the photographs are geometrically a correct central projection. But, due to the imperfections of the optical system, the passage of light rays through the lens and to the image plane is not on a correct straight line and the projection is not exactly central. The purpose of camera calibration is to evaluate the departures of the system from a prefect central projection. The systematic errors of interior orientation parameters could be modelled, corrected, eliminated, or negated.
Calibration of aerial cameras has been standardized over the decades but there is no standard procedure for CRP camera calibration and a number of simple or sophisticated approaches have been developed. Calibration models are typically a combination of physical and empirical terms, representing systematic errors in the perspective projection and commonly known as additional parameters(APs). The following table shows the most frequently used APs:

Parameter Name	Parameters and/or Models
Position of Principal Point	(x_o, y_o)
Principal Distance	C
Radial Lens Distortion	$\Delta r = k_1 r^3 + K_2 r^5 + K_3 r^7 + \ldots$
Decentring Lens Distortion	$\begin{cases} \Delta x = P_1\left[r^2 + 2(x - x_o)^2\right] + 2P_2(x - x_o)(y - y_o) \\ \Delta y = P_2\left[r^2 + 2(y - y_o)^2\right] + 2P_1(x - x_o)(y - y_o) \end{cases}$
Orthogonality and Affinity	$\begin{cases} \Delta x = A(y - y_o) \\ \Delta y = B(y - y_o) \end{cases}$

Table 1. Calibration Model

in which x,y are image coordinates and r is radial distance all with respect to thr principal point.

2 OPERATION DESCRIPTION

2.1 Test Area

The aim of this project was avaluation of the potentiallity of non metric cameras in precise and very precise architectural photogrammetry. For this purpose, rock relief of Dariush I, the Great(500 B.C.) in Bisotun was chosen as the test field. This glorious sculptures have been carved on an absolutely inaccessible vertical rock at about 70 meters above the terrain. This monument is one of the most important documents of the world cultural heritage. The working place was selected on the storeys of a huge scaffolding established by the Iranian Cultural Heritage Organization.

2.2 Equipment

To achieve the highest level of accurcies, the most precise available equipment were used as follows :
- Precise Non Metric Camera: Hasselblad 553 ELX
- Amateur Camera: Yashca FX-D
- Digital Camera: Minolta Dimage
- Phototheodolite: Wild P30
- Electronic Tacheometer: PowerSet 3000
- Very Precise Wild Reseau
- Very Precise Scanner: Intergraph PhotoScan TD
- Analytical Plotter: Leica SD2000
- Analogue Plotter: Wild A9
- Softwares: Microstation, Photoshop, Surfer, Monos

2.3 Network Design

Based on the principles of zero and first order design (ZOD & FOD) a preanalysis was performed considering the minimum number of control points,

Figure 1. Scaffolding (Scale ≈ 1:1000)

appropriate overlaps, and optimum base-to-distance ratio to avoid occluded areas. Hence, the configuration of the network was fixed and suitable instruments were selected.

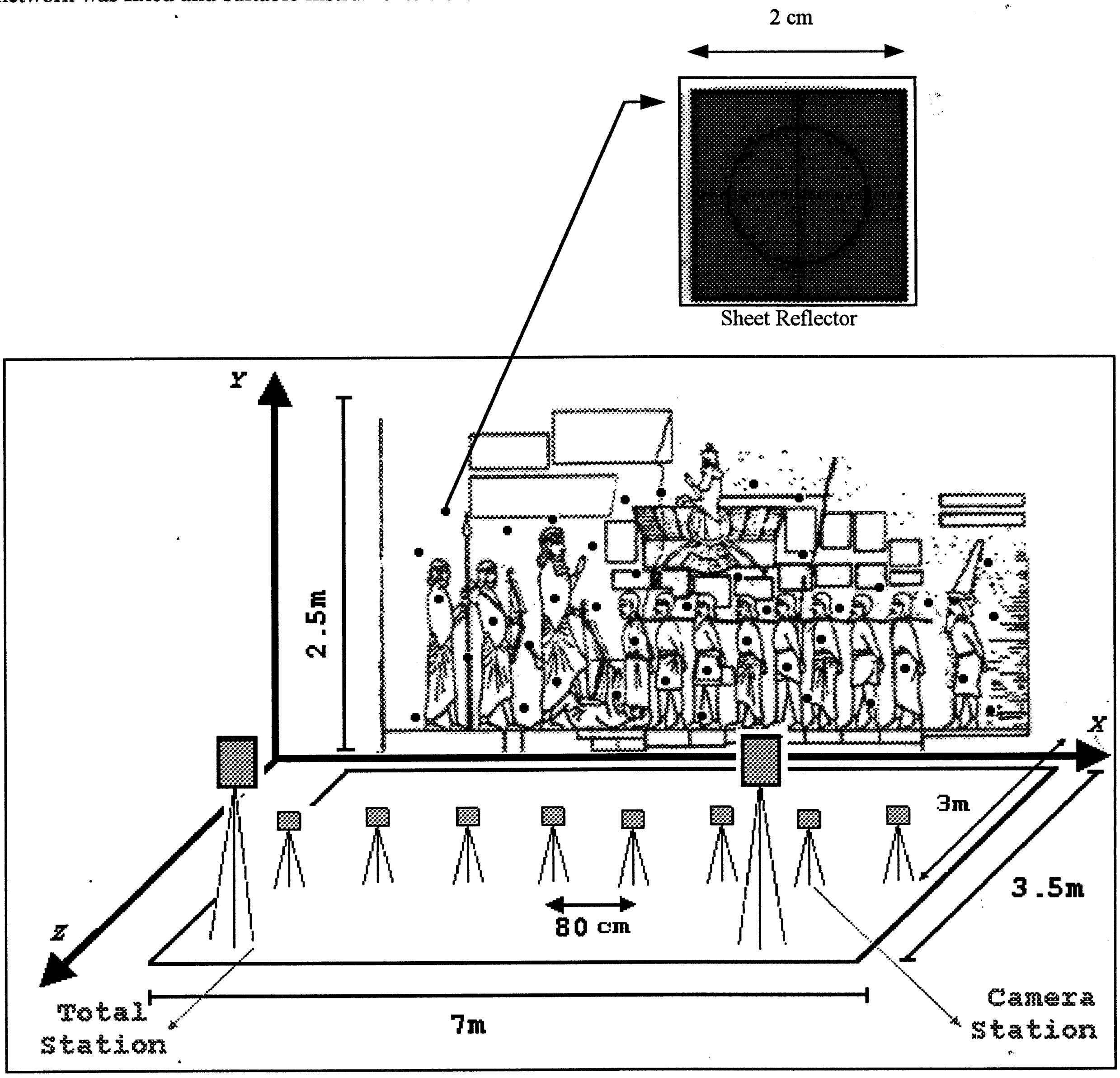


Figure 2. Camera Stations and Control Configuration

2.4 Image Processing

It was decided to apply a histogram equalization algorithm on the digital and scanned images in order to remove the occured blur and achieve a sharp viewing of the targets so that precise measurement of image points could be more easily performed. In a histogram equalization procedure, the gray values are extended over a wider domain, for example from [70-120] to [20-230].

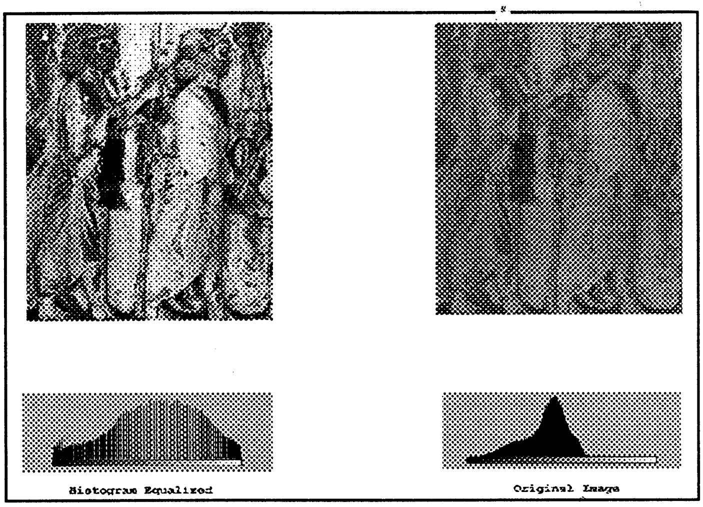


Figure 3. Histogram Equalization

2.5 Calibration

Based on the principles previously mentioned the calibration parameters of cameras were determined by applying the augmented collinearity equations on six convergent photographs with 100% overlap that could provide a suitable redundancy leading to a robust estimate of APs.

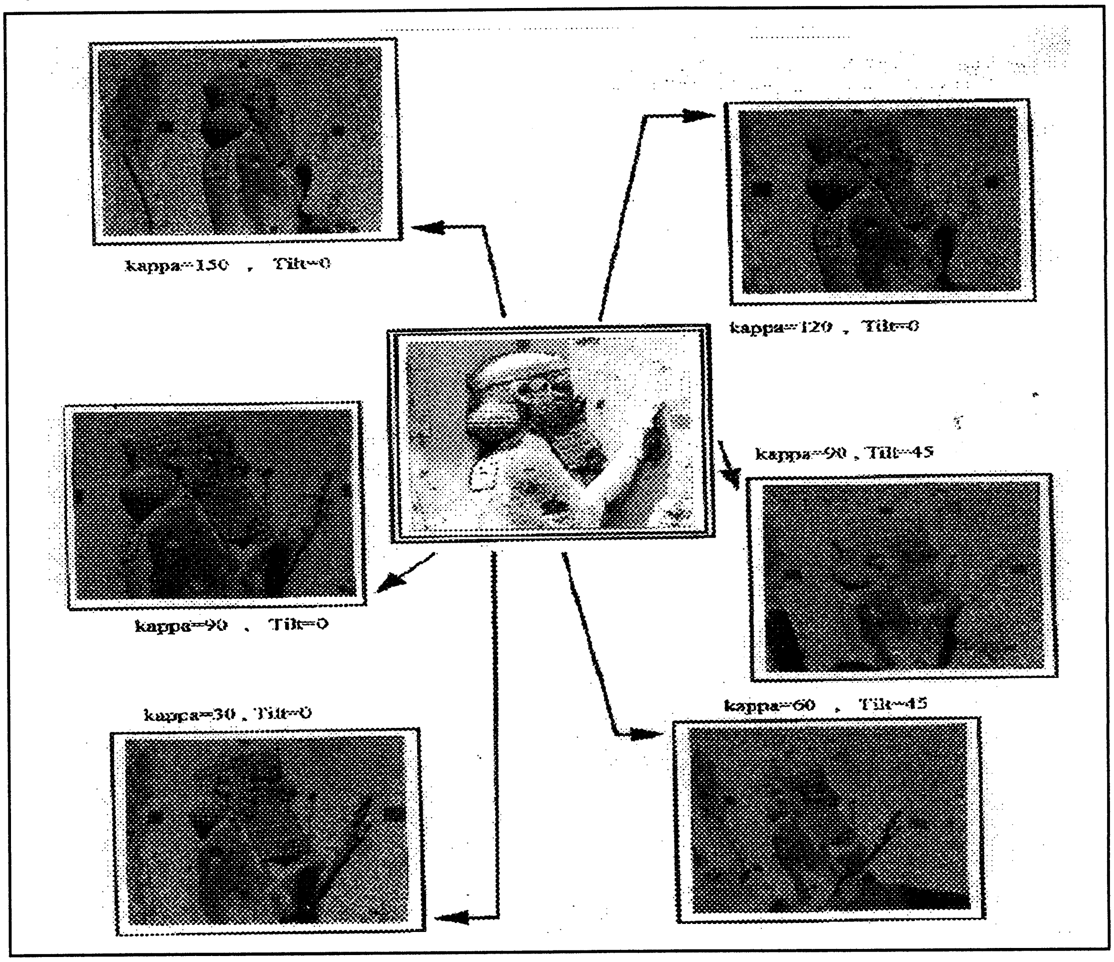


Figure 4. Convergent Photography for Calibration

The results of camera calibration are given in the following table:

K_1	K_2	K_3	P_1	P_2	A	B	x_o	y_o	C
.00005	.00000	.00000	.00003	.00002	.00006	-.00004	.00690	.00720	102.35300

Table 2. Calibration Results for Hasselblad 553 ELX (in mm)

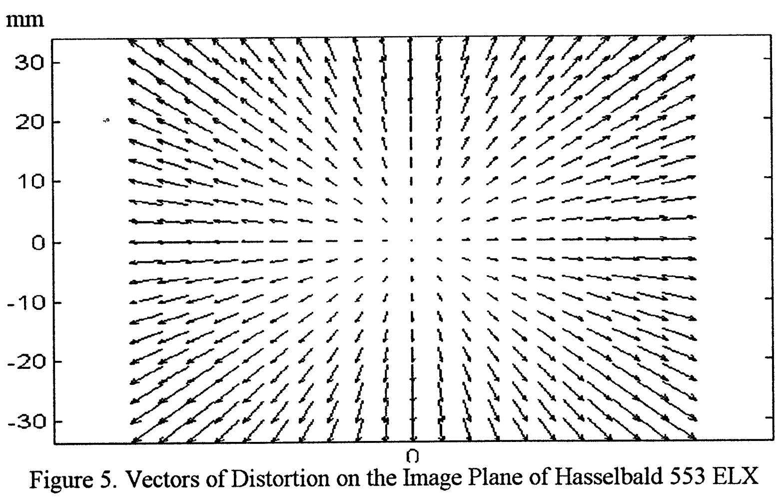
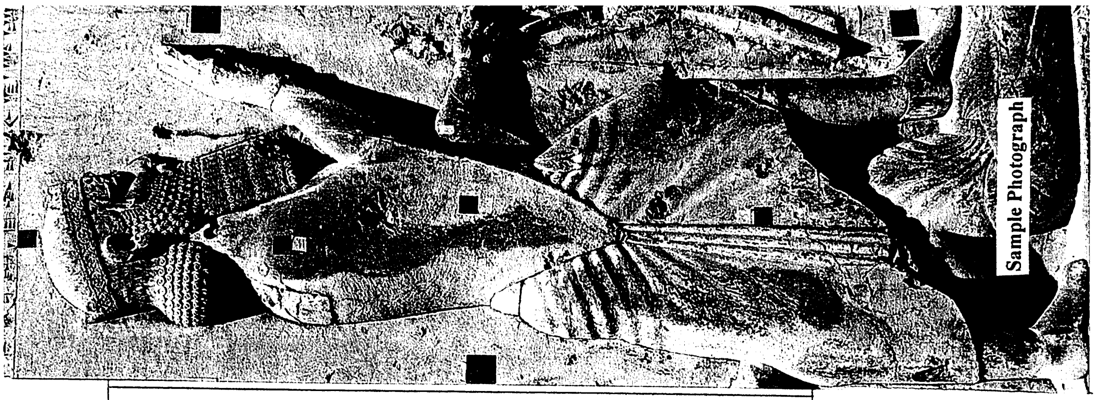


Figure 5. Vectors of Distortion on the Image Plane of Hasselbald 553 ELX



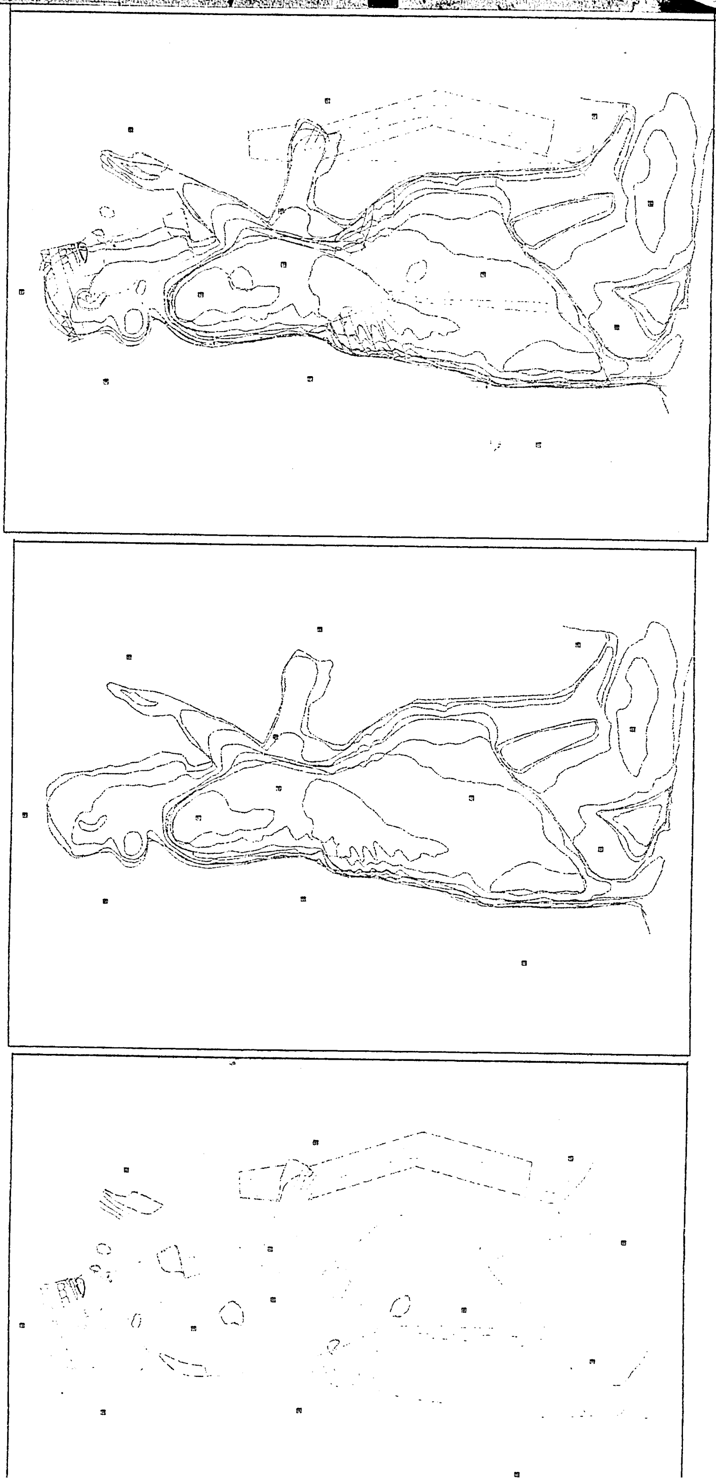


Figure 6. Analytical Restitution of Amateur Camera

2.6 Stereoplotting

To have a comparision between amateur and precise non metric cameras, both analogue(Wild A9) and analytical (Leica SD2000) plotters were used. A sample output of the analytical stereoplotting is shown in figure 6. The obtained accuracies are given in the following table:

Camera Type	Analytical Restitution		Analogue Restitution	
	RMS_{xy}	RMS_z	RMS_{xy}	RMS_z
Hasselblad	0.83	2.06	0.94	2.50
Yashica	1.91	4.20	------	------

Table 3. Root Mean Squares of Check Points (in mm)

2.7 Digital Surface Model(DSM)

After analytical restitution, a regular grid was read and densed by means of an MDL program in Microstation media. The resulted XYZ file was then converted to a DSM of the desired sculptures.

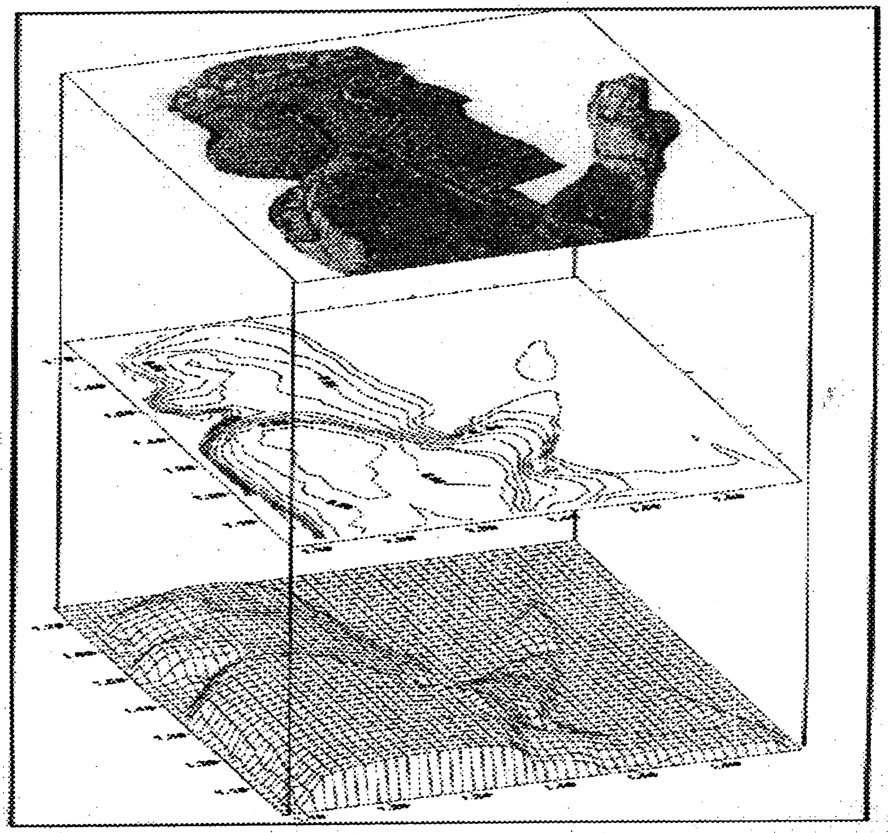


Figure 7. DSM

2.8 Digital Rectification

For digital rectification, the Monos software written by Dr. Azizi was used. In this process, gray value interpolation was performed by bilinear transformation and a RMS of 0.21 for x and 0.13 for y was achieved.

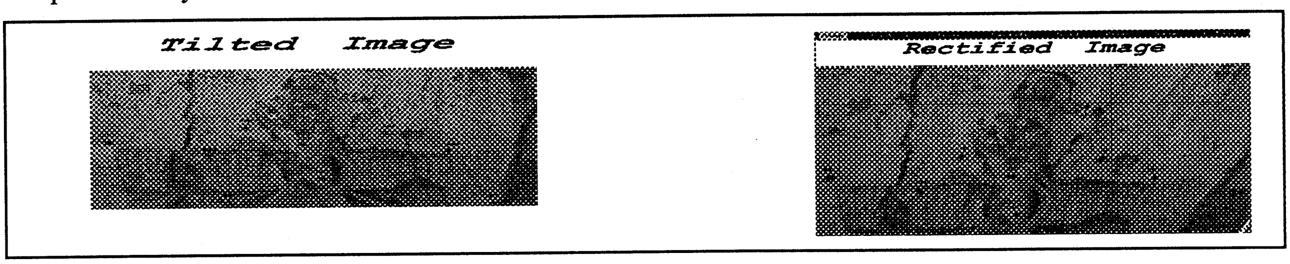


Figure 8. Digital Rectification

3 CONCLUSIONS

It was shown from the survey conducted within this paper that; non metric camera can have an increasing application in architectural photogrammetry for recording cultural heritage. By considering a suitable mathematical model of calibration, a precise non metric camera like Hasselblad 553 ELX may be used for any kind of architectural photogrammetric maps satisfying the ICOMOS standards. Also, the calibrated amateur cameras like Yashica FX-D can be used for producing simple and precise categories of architectural maps. Furthermore, the capability of non metric cameras for rectification in heritage recording is verified.

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